

# *The Reactive Bridge: A Novel Solid-State Low Energy Initiator*

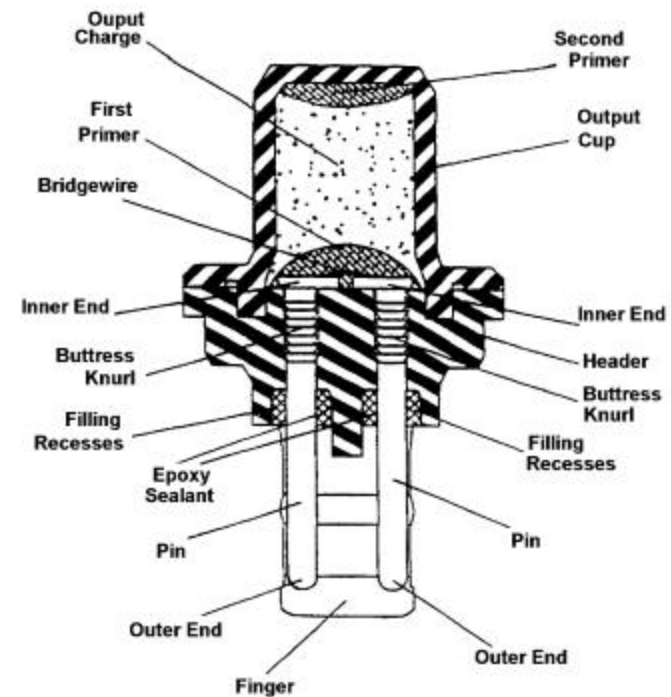


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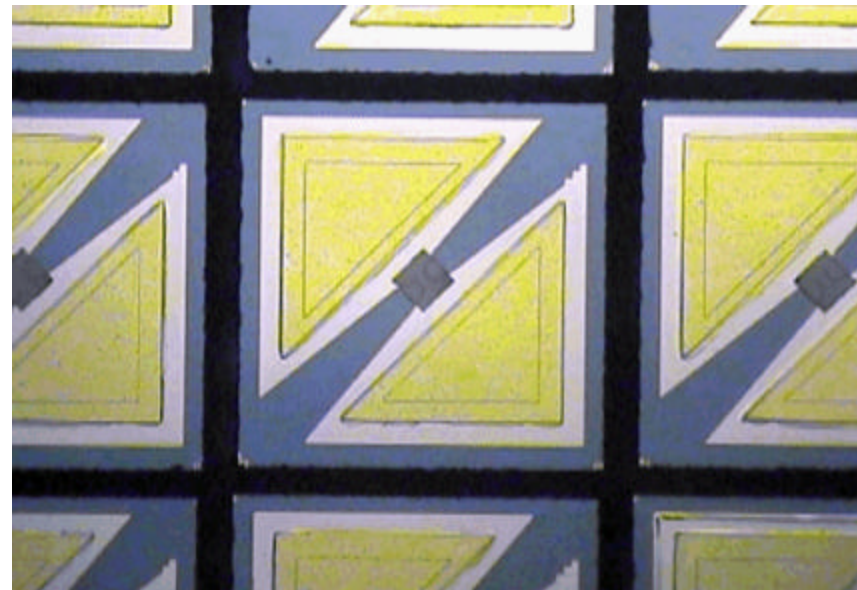
# *EED Structure*

- Conductive Pins
- Header and Cup
- Bridgewire
- Primary Charge
- Output Charge



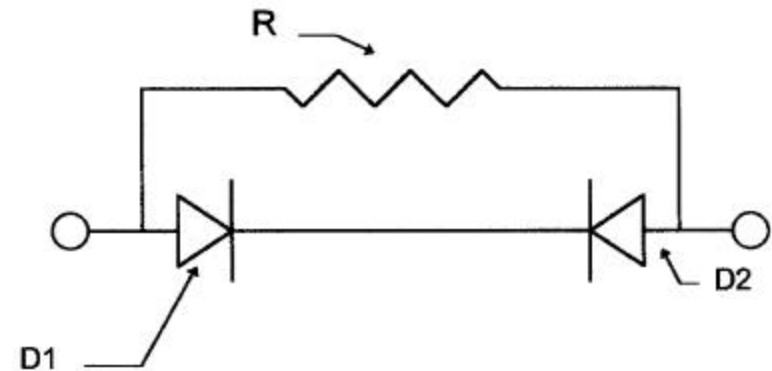
# *Reactive Bridge vrs. Bridgewire*

- Faster Actuation ( $<5\mu\text{sec}$ )
- Lower Firing Energy ( $<30\mu\text{J}$ )
- Smaller Dimensions (Feature size  $<20\mu\text{ms}$ )
- Reliable Ignition Across Airgap
- Insensitive to ESD
- Fabricated with Conventional Microelectronic Processes



# *Design Model*

- Resistive Heating Element ( $1\Omega$  -  $10\Omega$ )
- Two PN Junction Diodes in Parallel for ESD Protection (Breakdown Voltage  $\sim 4V \Leftrightarrow 20V$ )



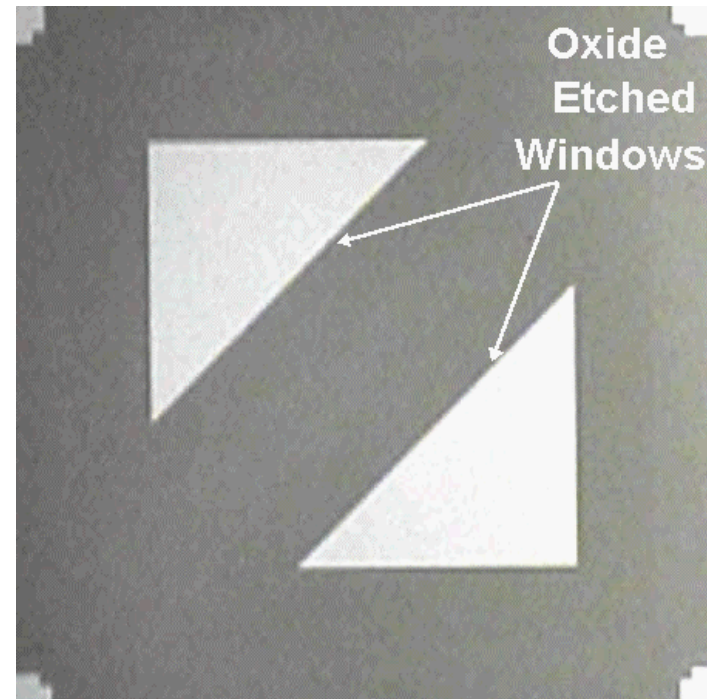
# *Composite Reactive Bridge Fabrication*



- Utilizes Basic Fabrication Techniques
- Photolithography
- Wet Chemical Etching
- Sputtering and E-beam Metal Deposition
- Liftoff Process

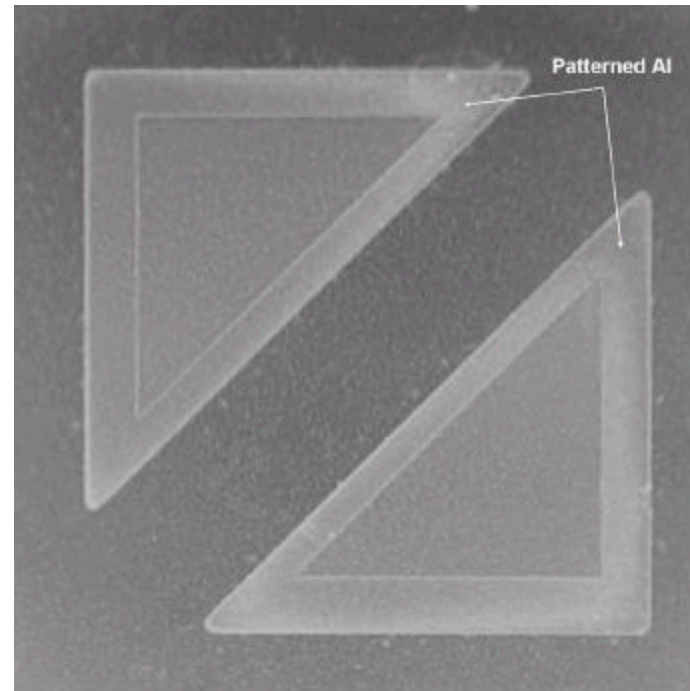
# *Implant and Diffusion*

- Etch Oxide Window using BOE
- Typical Ion Implant
  - B
  - $Q = 5E15/cm^2$
  - Energy = 50keV
- Typical Drive-In
  - 1000°C, N<sub>2</sub>
  - 15 minutes



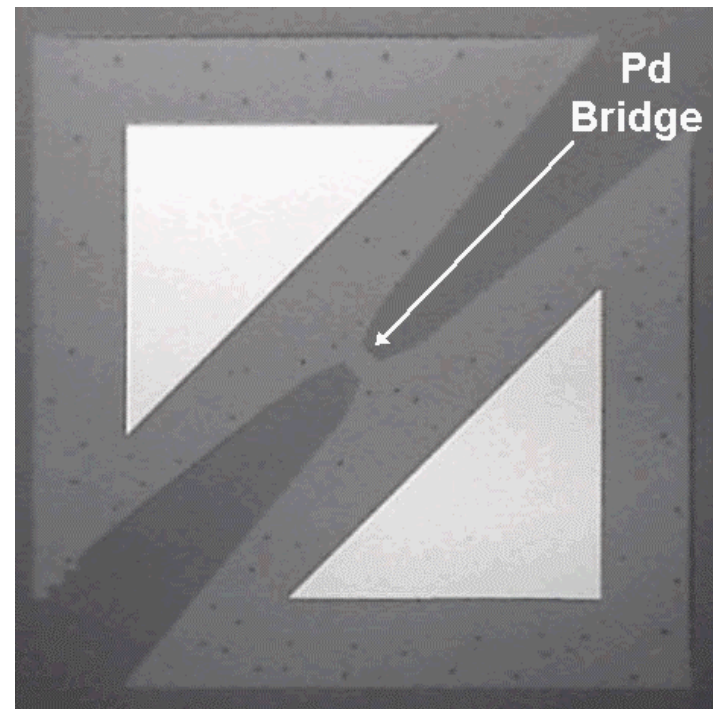
# *Aluminum Deposition*

- Sputter  $\sim 12,000\text{\AA}$  of Si/Al
- Mask off Window
- Etch Al with PAE
- Etch Residual Si
- Alloy Al at  $450^{\circ}\text{C}$  for 30 minutes



# *Palladium Deposition*

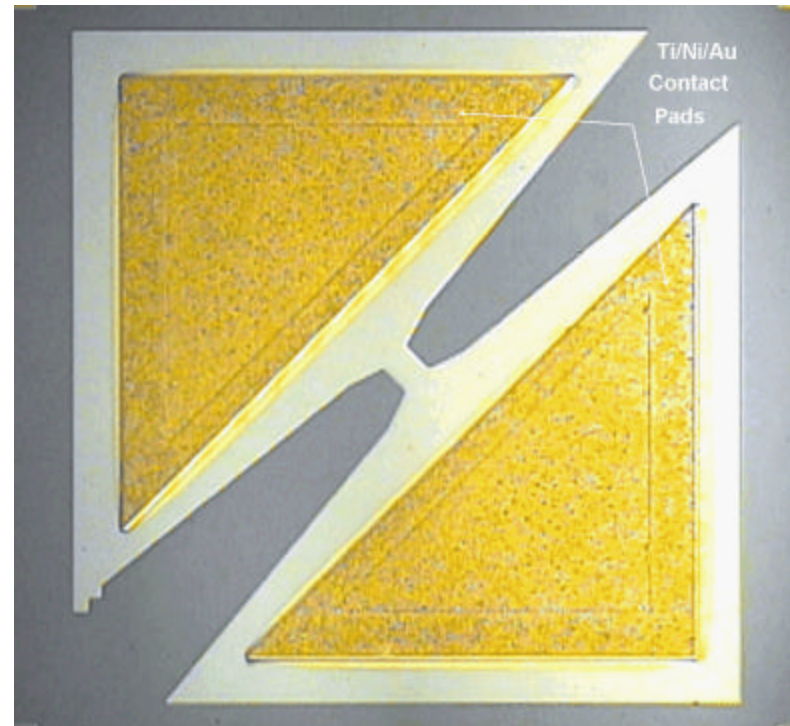
- Mask and Develop
- Deposit
  - 500Å of Ti
  - 2000Å of Pd
- Liftoff
  - Ultrasonic and Acetone





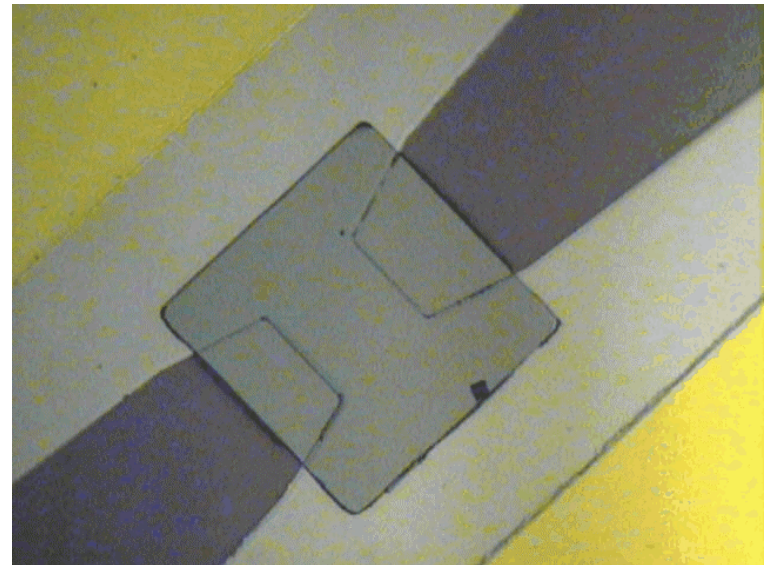
# *Gold Deposition*

- Mask and Develop
- Deposit
  - 500Å of Ti
  - 1000Å of Ni
  - 2000Å of Au
- Liftoff
  - Ultrasonic and Acetone



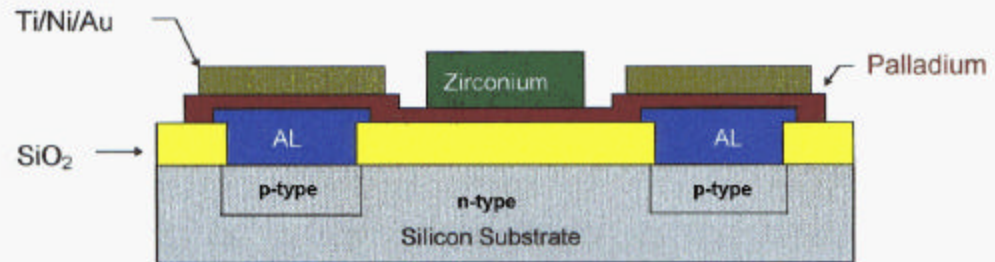
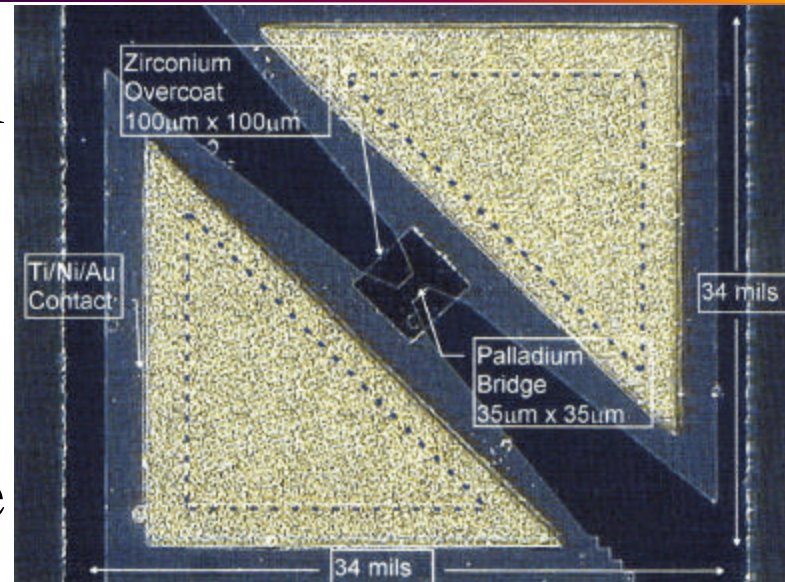
# *Zirconium Deposition/Reactive Overcoat*

- Mask and Develop
- Deposit
  - 500Å of Ti
  - 10,000Å of Zr
- Additional Mass for Plasma Formation
- Chemically Reactive
- Liftoff
  - Ultrasonic and Acetone



# Typical Dimensions

- ~1mm x 1mm, overall size
- $15\mu\text{m}^2$  -  $40\mu\text{m}^2$ , varying bridge size
- $100\mu\text{m}^2$ , overcoat size



# *Packaging*

- ValoxDR48 Plastic Header
- Conducting Pins
- Output Cup





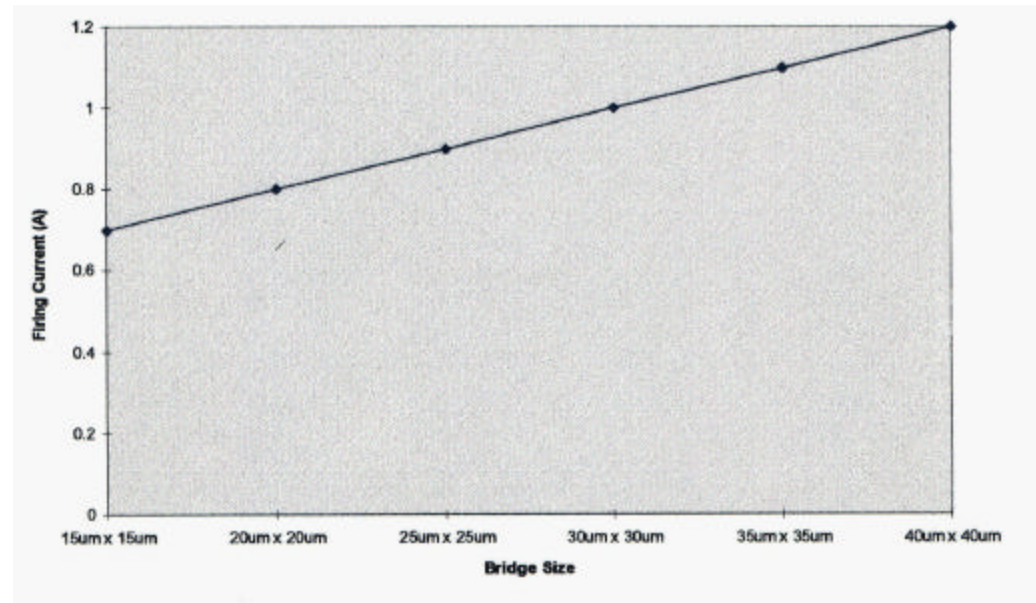
# *Design Validation Testing*

- Firing Current  
Proportional to Bridge  
Size

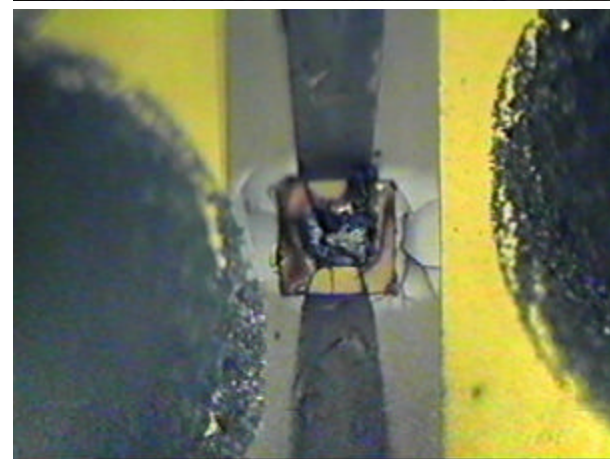
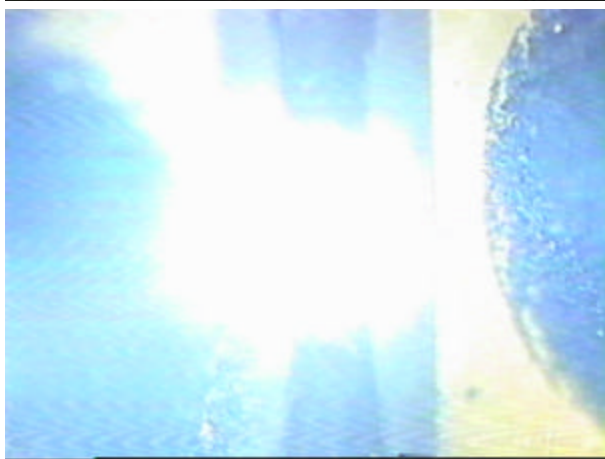
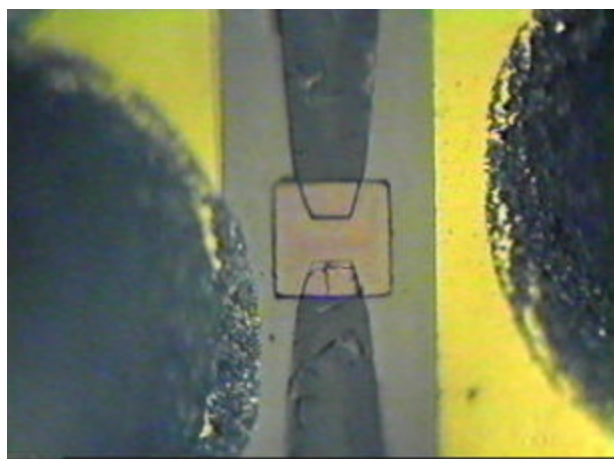
- Firing Energy,

$$Q = \int_0^t (I^2 R) dt$$

- I = Firing Current
- R = 2Ω (bridge)
- t = .1msec

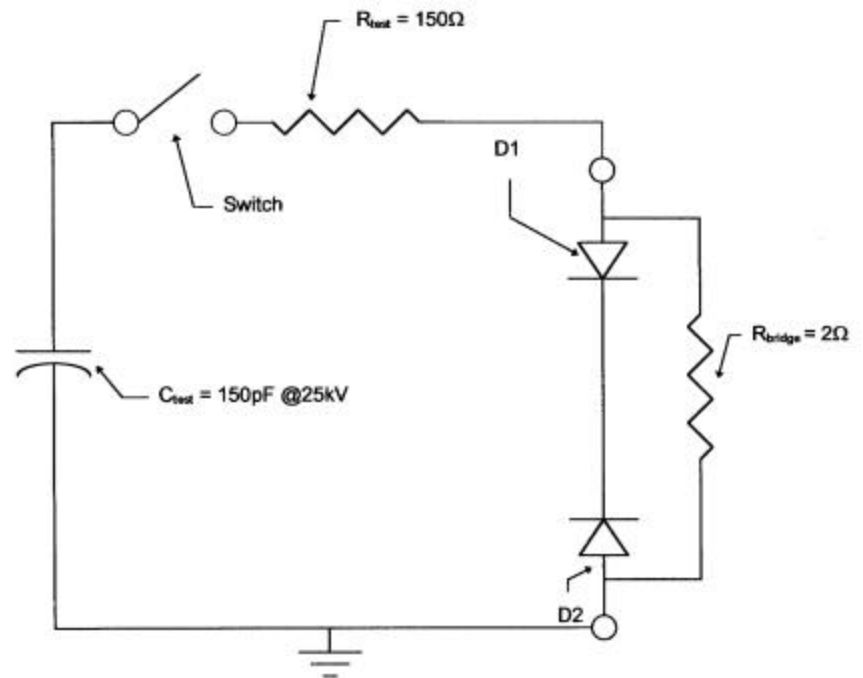


# *Firing Results With /Without Overcoat 2mF@30V*



# *ESD Test Setup*

- 150pF Capacitor  
Charged to 25kV
- Series Resistor of  
150Ω
- Close Switch
- Repeat 5 times



# *Environmental Test Setup*



- 320 Parts
- High Temp, 144 hrs @ 107°C
- Thermal Shock and Humidity
  - 6 cycles(-40°C and 107°C) for 12 hrs
- Random Vibration
  - Method S14:4 category I
  - 3 perpendicular axis, -40°C, 21°C, and 90°C



# *All Fire/No Fire Data*



## **All Fire / No Fire Summary**

Group	Bond	AF @ 1ms, 99.999% @ 95% Confidence -40C	AF @ 1ms, 99.999% @ 95% Confidence +21C	NF @ 10s, 99.999% @ 95% Confidence +90C	NF @ 10s, 99.999% @ 95% Confidence +21C
Baseline	Wirebond	1.037A	NA	.583A	NA
Post Serial Environ.	Wirebond	1.039A	NA	.617A	NA
Baseline	Conductive Epoxy	1.026A	NA	.613A	NA
Post Serial Environ.	Conductive Epoxy	1.040A	0.997A	.613A	.605A

# *Validation Testing Results*



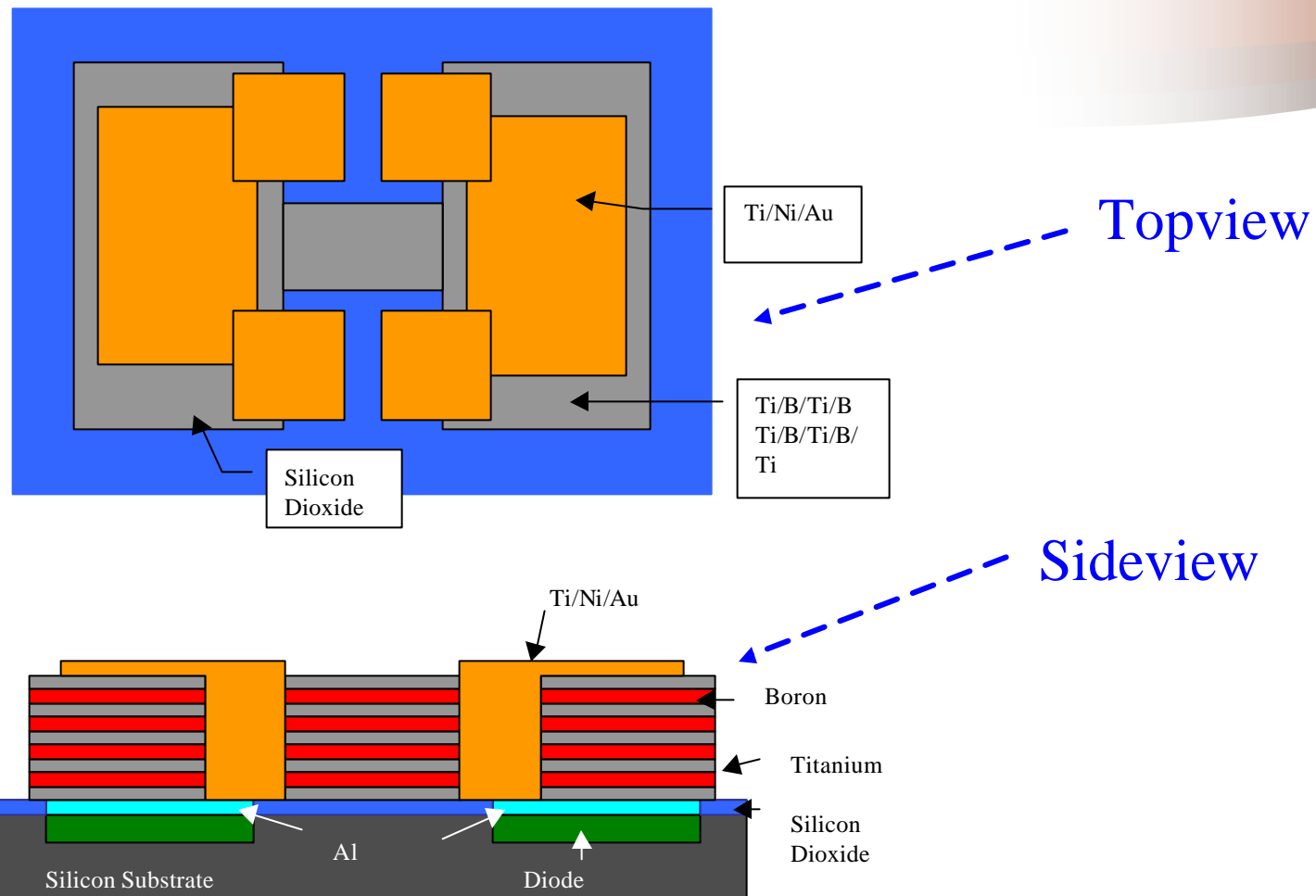
- Results Extremely Positive
- 1.2A, 1msec all-fire
- 0.5A, 10s no-fire
- 99.999% reliability, 95% confidence
- Time to Peak Pressure, < 1ms

# *The Laminated Reactive Bridge*



- Structure employs laminations of B/Ti
- Exothermic inter-metallic alloy
- No oxidizer required
- $2\text{B} + \text{Ti} \Rightarrow 1320\text{cal/gm}$

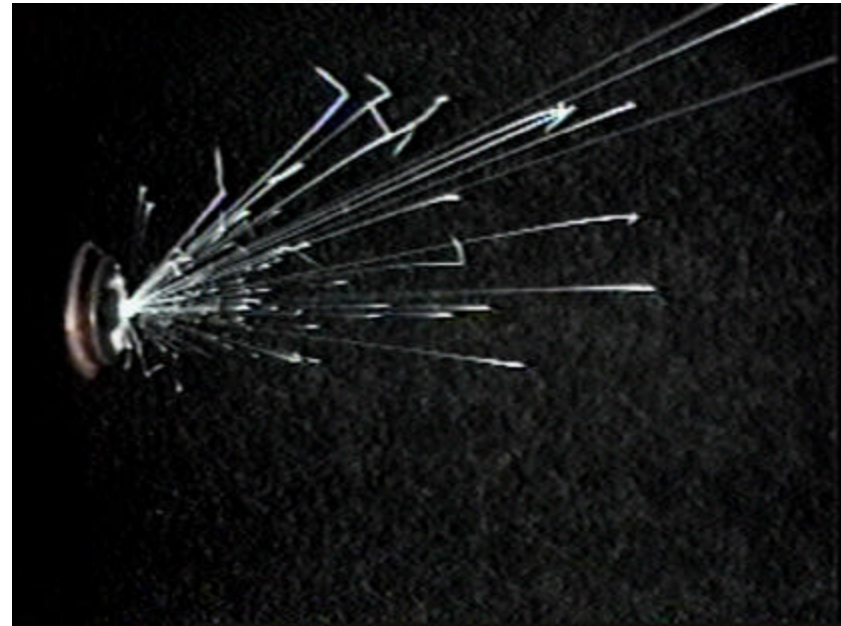
# *Laminated Reactive Bridge*



# *Sample Firing Of Laminated 110mm Bridge 35mF@30V*

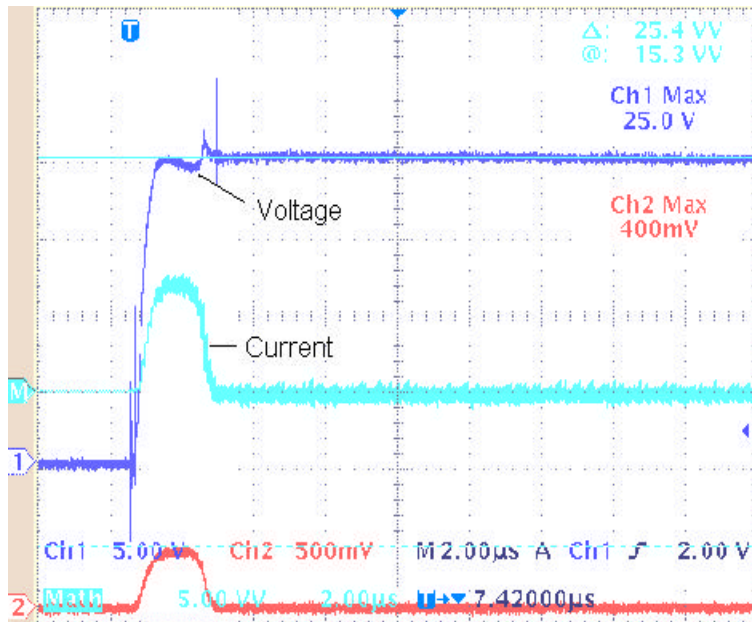


← 4cm →

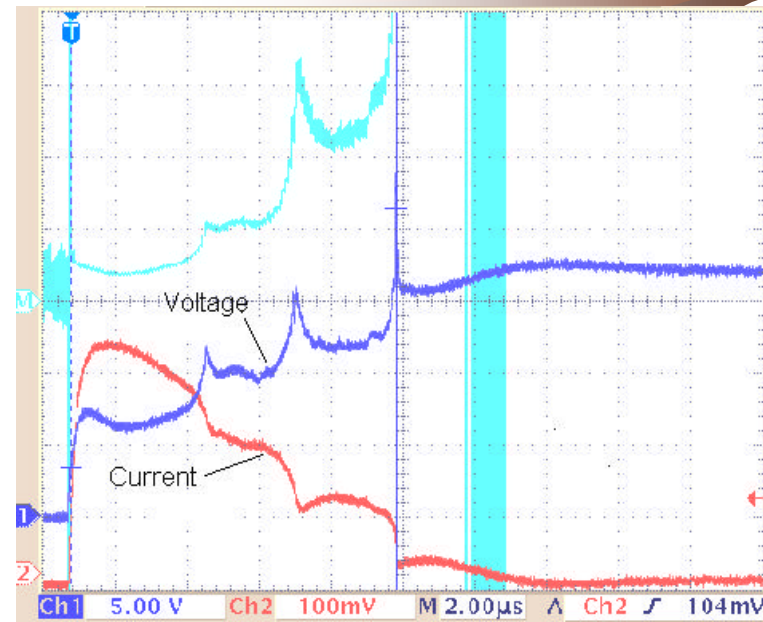


← 4cm →

# *Firing Current Waveforms*

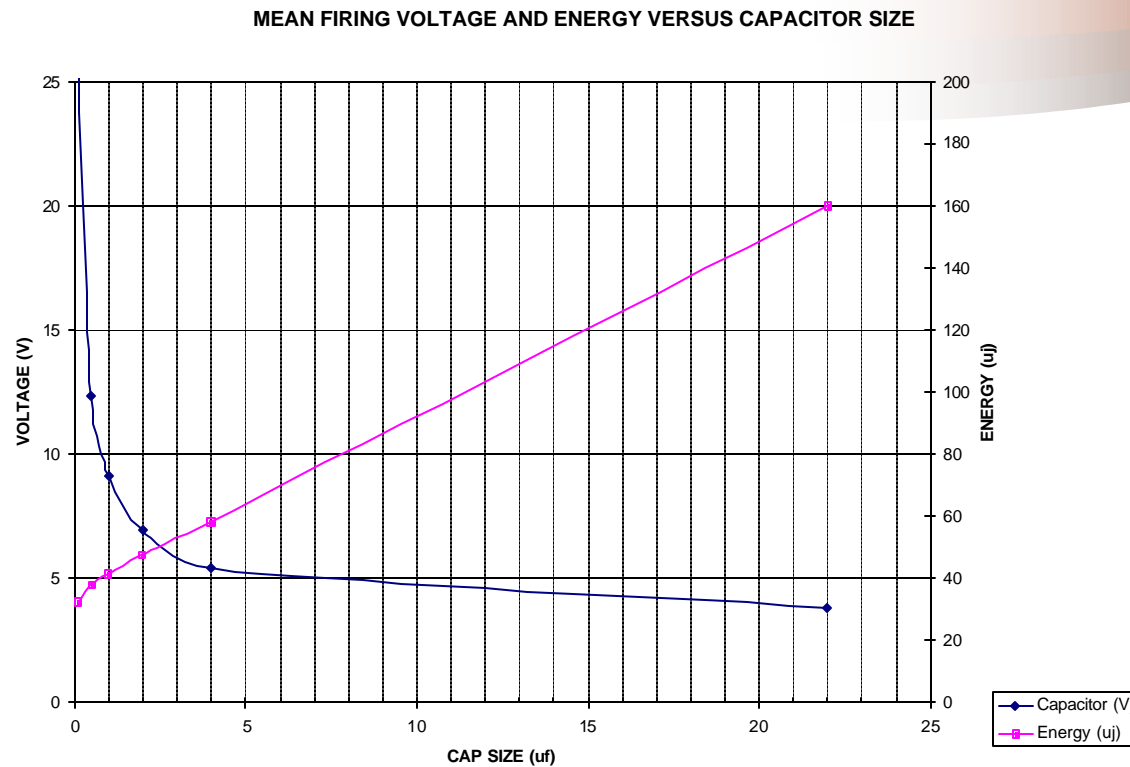


Typical Firing Trace of a Composite Bridge  
(30μm bridge)



Typical Firing Trace of a Laminate Bridge  
(30μm bridge)

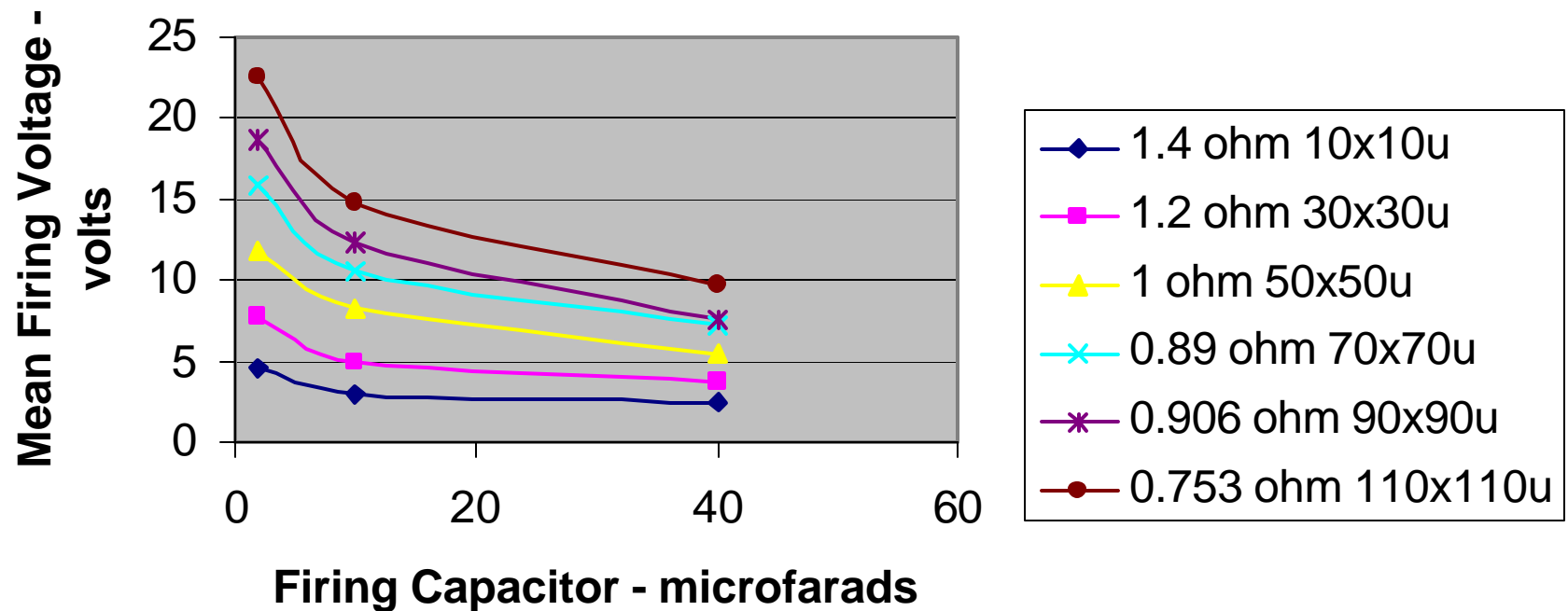
# *Firing Characteristics of Laminated Bridge with 5W ESR*



A plot of firing voltage and energy for a 20  $\mu\text{m}$  Laminated bridge

# *Firing Data for Laminated Bridge*

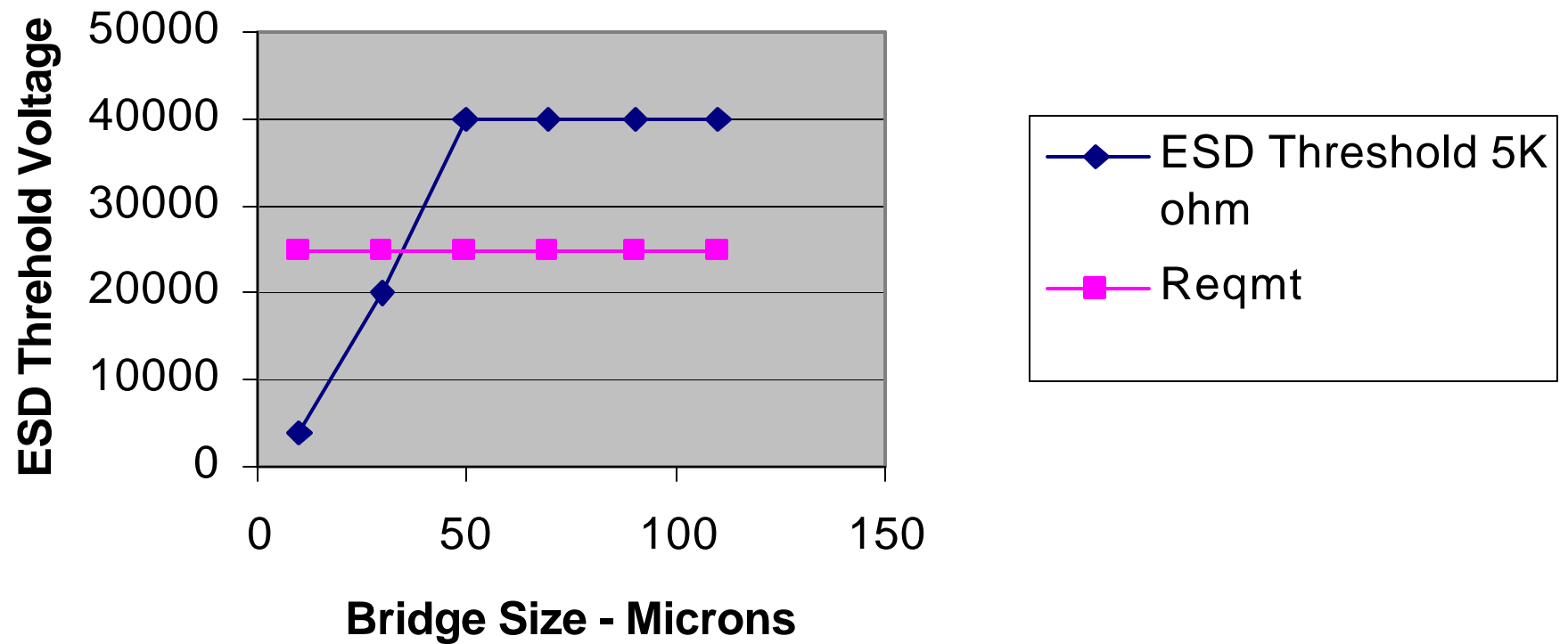
**Reactive SCB Mean Firing Voltage Vs  
Capacitance & Bridge Size**



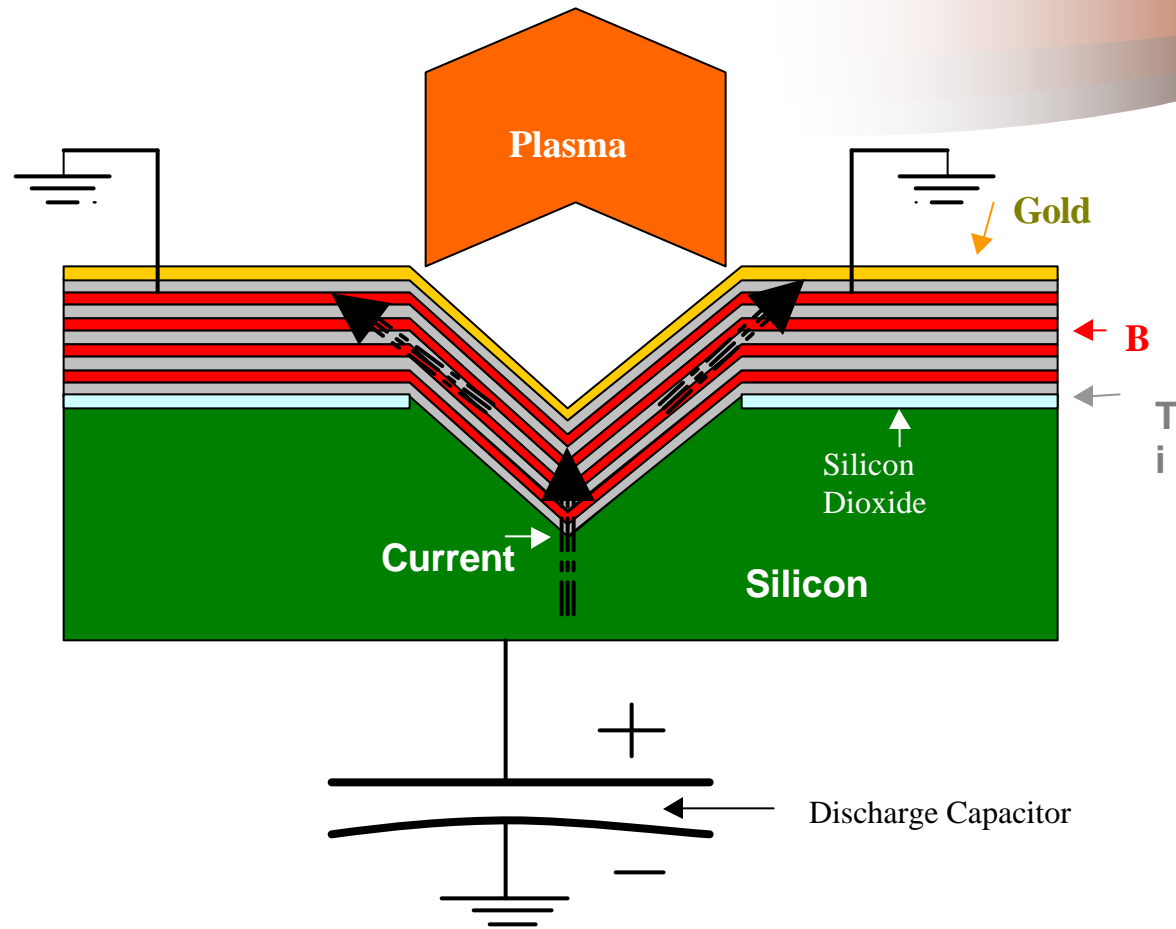


# *ESD Results for Laminated Bridge*

**ESD Threshold Voltage (500pf 5K ohm)**



# *Integrated Shaped-Charge*



# *Conclusion*



- Devices Fabricated Using Conventional Techniques
- Demonstrates Lower Firing Energy
- Diodes Protect Against ESD Events
- Reliably Fires in Less Than 1 $\mu$ sec
- Plasma Output Capable of Jumping a Gap
- Very Economical for Large Volumes